METHOD AND SYSTEM FOR AGGREGATING AND COMBINING MANUFACTURING DATA FOR ANALYSIS

CROSS REFERENCE TO RELATED APPLICATIONS

5   This patent application is related to U.S. Patent Application Serial Number _____ (Attorney Docket No. 303.884US1), entitled METHOD AND SYSTEM FOR CORRELATING AND COMBINING PRODUCTION AND NON-PRODUCTION DATA FOR ANALYSIS, to Naoki Toyoshima, Shinichi Murakami and Yuko Maeda, assigned to Micron Technology, Inc., and incorporated herein by

10   reference.

TECHNICAL FIELD

The present invention generally relates to integrated circuit manufacturing. The present invention also generally relates to methods for reducing integrated

15   circuit manufacturing abnormalities. The present invention also generally relates to a method to aggregate and combine data from integrated circuit manufacturing processes for data analysis.

BACKGROUND

20   Defects in semiconductor manufacturing processes result in lost production and fabrication downtime. The cause of these defective products is hard to determine as today's manufacturing processes involve not only a single manufacturing operation but multiple instances of the same operation performed by different machines and a multitude of other processes and machines. Identifying the

25   cause of the error is in itself time-consuming and the large amounts of data to examine makes quick and accurate analysis difficult.

During the semiconductor manufacturing process the unprocessed wafer proceeds through several distinct manufacturing processes. Measurements are taken during this process and analyzed. If the analysis shows that a problem is occurring

30   the process is stopped and the condition resolved before production is allowed to resume. These processes can become very complicated and data analysis may not

be able to be completed and studied until well after the time that the particular wafer that had been processed has been completely processed by the faulty process.

Further compounding the lag time between the measurement and the analysis and then the subsequent reaction is that for a single process, a number of machines may perform that same exact process. The number of measurements taken during this manufacturing process expands linearly and data analysis is no longer cumbersome, it is impossible. Anomalies in the processes are not identified quickly enough and entire lots of end-product may be defective as a result.

The problem is that there is no easy way to combine the data and reduce the data processing time so meaningful data analysis can take place and reaction to current conditions can take place quicker. What is needed is a way to aggregate processes and resulting data for the purposes of analysis.

SUMMARY OF THE INVENTION

An embodiment of the present invention relates to a method of utilizing computer aided data analysis to detect manufacturing process abnormalities. Embodiments of the present invention aggregate data. Examples of the data include online and offline data, which are collected from a variety of sources. This method makes it possible to collect data powerfully within a few hours, allowing enough time for an engineer to make decisions as to process control. For instance, they can make a precise decision to stop or continue a particular manufacturing process based on the analyzed data if that analysis indicates that the process is having a problem.

An embodiment of the present invention is a method for detecting conditions in an electronic device manufacturing process. In an embodiment the electronic devices are integrated circuits. The method includes grouping a first, second, third and further groups of processes that are related in some manner. An embodiment further identifies the routes that a production lot of workpieces may take through the possible groups. An embodiment further assigns that route's measured data items to the data set of the production. An embodiment further adds manufacturing performance data specific to that route to the data related to that production lot. An embodiment further performs an analysis on that data.

In an embodiment the analysis is examined for the occurrence of out of specification readings or trends. The occurrence of such readings or trends results in the possible notification of the users or engineers responsible for the proper functioning of the process.

5   In an embodiment the method for detecting and responding to conditions in an electronic device manufacturing process is performed by a computer system which includes at least some of: a processor, output device, input device, bus, and a storage device which contains instructions to carry out the method taught by the present invention.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a pictorial representation of an exemplary fabrication facility with fabricating processes contained therein.

FIG. 2 is a pictorial representation of a scenario of an embodiment of the
15   present invention.

FIG. 3 is a flowchart illustrating generally a method according to an embodiment of the present invention.

FIG. 4 is a pictorial representation of a scenario of an embodiment of the present invention.

20   FIG. 5 is a flowchart illustrating generally a method according to an embodiment of the present invention.

FIG. 6 is a flowchart illustrating generally a method according to an embodiment of the present invention.

FIG. 7 is a block diagram illustrating generally, among other things, one
25   example of portions of a data analysis system, and an environment with which it is used, for processing and analyzing the data acquired from the manufacturing process.

FIG. 8 is a pictorial representation of an exemplary fabrication facility with fabricating processes contained therein.

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DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description of exemplary embodiments of the invention, reference is made to the accompanying drawings (where like numbers designate like elements), which form a part hereof, and in which is shown by way of

5 illustration specific exemplary embodiments in which the invention may be practices. Those embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and logical, mechanical, electrical and other changes may be made without departing from the scope of the present invention. In the

10 description, numerous specific details are set forth to provide a thorough understanding of the invention. However, it is understood that the invention may be practiced without those specific details. In other instances, well-known circuits, structures and techniques have not been shown in detail in order not to obscure the invention.

15 Parts of the description may be presented in terms of operations performed through the execution of programming instructions. As well understood by those skilled in the art, those operations may take the form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, and otherwise manipulated through, for example, electrical components.

20 The term substrate is understood to include semiconductor wafers. The term substrate is also used to refer to semiconductor structures during processing, and may include other layers that have been fabricated thereupon. Both wafer and substrate include doped and undoped semiconductors, epitaxial semiconductor layers supported by a base semiconductor or insulator, as well as other

25 semiconductor structures well known to one skilled in the art. The term conductor is understood to include semiconductors, and the term insulator or dielectric is defined to include any material that is less electrically conductive than the materials referred to as conductors. In embodiments of the present invention, the term workpiece includes substrate or wafer or integrated circuits or other electronic

30 devices.

The term lot is understood to include a subset of the entirety of fabricated workpieces. A lot may further be considered as that quantity of product produced under similar conditions, at a similar establishment, over some period of time.

The terms operation, machine, process, and chamber are used in the present application to describe various abstractions of the fabrication process. In an embodiment, an operation is a top level abstraction and may include subdivisions, such as, machines, processes, chambers, etc. It is to be understood that an operation may also be subdivided into further operations, according to an embodiment of the present operation for other abstracted analysis of data. In a further embodiment of the present invention, top-level operations may be further aggregated, up and including, considering an entire manufacturing facility as a single operation. In an embodiment, a machine is a mid-level abstraction and may include subdivisions, such as, processes, chambers, etc. In an embodiment, the term machine is not to be taken in a limiting sense as a single physical machine, but in a more broader sense as a collection of processes, chambers, other machines, etc. In an embodiment, a machine may denote the aggregation of multiple machines, including the subdivisions, if any, of such machines. In an embodiment, a process is a low-level abstraction and may include subdivisions, such as, chambers. In an embodiment, a process is a mid-level abstraction and may include subdivisions, such as, machines, chambers, etc. In an embodiment, a process may denote the aggregation of multiple processes, including the subdivisions, if any, of such processes. In an embodiment, a chamber is a low-level abstraction and typically will not include further subdivisions. In an embodiment, a chamber may denote the aggregation of multiple chambers and may include further subdivisions. Though the terms operation, machine, process and chamber are used to represent a hierarchical linking between manufacturing steps, this is not limiting. It is to be understood that an operation may be a single machine, an aggregation of machines, a single process, an aggregation of processes, a single chamber, an aggregation of chambers, or any combination. Further, any of the other steps, such as a process, may be performed by any combination of the other steps. For example, an operation may include wafer handling unit chambers which·perform a process on a wafer. It will be

understood by those skilled in the art, that any subdivision of manufacturing steps can be used by embodiments of the present invention, and that mere use of other terms to denote manufacturing steps does not depart from the scope of the present invention

5   FIG. 1 depicts a pictorial representation of a simplified manufacturing process for workpieces. Workpieces, in an embodiment, include integrated circuits. Workpieces for processing **105** enter the manufacturing process and are processed, in this simple example, by three separate operations **110, 120**, and **130**. It is recognized that though the term operation is used, the term operation may include

10   any number of machines, chambers, processes, etc. Further, the operation may include a single machine, chamber, process, etc. Conditions in the operations performing the processing are very important to the end quality of the finished product **106**. In addition, the conditions of the manufacturing facility **100** may also impact the quality of the end product **106**. In an embodiment, a manufacturing

15   facility includes an integrated circuit fabrication building, wafer handling unit, vertical furnace machines, computer component assembly facilities, etc. It is recognized that each of these manufacturing operations may further be subdivided. These subdivisions represent the technique of using multiple machines, chambers, processes, etc. to perform the same operation. In **110**, this is exemplified by the

20   four individual machines, Machine A_1 **111**, Machine A_2 **112**, Machine A_3 **113**, and Machine A_4 **114**. Each of these machines performs a substantially similar operation to respective workpiece being processed in the respective machine. However, data relating to one machine **111, 112, 113** or **114** is not relevant to the other machines. For example, data in regards to Machine A_3 **113** for example, would be of no

25   relevance to a workpiece that was processed by Machine A_1 **111**. Capturing data for Machine A_3 **113** and including that data in an analysis of conditions for workpieces processed by Machine A_1 **111** carried out by a data processor **140** would represent a computational cost that prohibits the real time analysis of data relating to machine A_3 **113** and further prohibits accurate, real time analysis of the entire operation **110**.

30   This results in workpiece lots progressing further down the operational chain and when the data finally yields results that an operator or system can react to, resources

have been wasted on the lots in further processing. In an extreme case, this may lead to scrapping entire lots of workpieces. Though the operation at **110** is subdivided into machines, it is recognized that there are other subdivisions possible, including subdividing an operation into other operations, chambers, machines,

5   processes, etc.

Data may also be measured on the operations at **120** and **130**. These operations may further be subdivided. In an embodiment, this subdivision is similar to the subdivision presented in Operation A **110**, as described above. In an embodiment, this subdivision is performed by some other logical arrangement, such

10   as, consecutive non-similar machines being subdivided by the possible route that a workpiece may take through the operation. In such an arrangement, data is acquired for workpieces depending on the route the workpieces took, and stored in a data set relevant to the workpiece being examined, for further analysis by a data processor **140**. Data concerning Operation C **130** is acquired for workpieces being processed

15   according to the operation subdivisions contemplated for Operation C **130**. Data acquisition for a particular production lot of workpieces is only performed from sources that relate to the processing that the particular lot of workpieces underwent. This reduces the amount of extraneous data being collected and stored and allows for quicker data analysis. This has the added benefit of providing for quicker

20   response to conditions present in the fabrication operations.

Measurements may be taken on the workpiece **105** as well as conditions of the actual manufacturing operations **110, 120, 130**. These measurements can be called production data. The production data is from sources that are directly related to the manufacturing process being performed. These sources include, but are not

25   limited to, test probe data, parametric data, film thickness data, and critical dimension data. In an embodiment, a particular production data sample is gathered once per lot, i.e., production lot data. In an embodiment, a particular production data sample is gathered multiple times per lot. In an embodiment, a particular data sample is applied across multiple production lots. Though this detailed description

30   uses the term production data to refer to these data measurements, this is not to be taken in a limiting sense, as any data that relates directly to the manufacturing

process being performed is considered to be production data, regardless of what it is actually called. Further, production data may be further defined as being either online or offline. Online data may be data which is measured directly on the workpiece being manufactured and may be things such as the temperature of the

5 manufactured workpiece, or its thickness. Online data may also be data measured from the manufacturing process in question while the workpiece is being processed. Offline data is that data that, though directly related to the manufacturing process, is not measured on the actual manufactured workpiece or during the actual manufacturing step, such as the operating temperature of the machine, the operating

10 pressure, critical dimensions data on a finished workpiece, or some other measurement.

The pictorial element labeled **100** represents the entire facility in which the manufacturing process resides. Measurements may be conducted on the entire facility, as well. These measurements can be called non-production data or

15 alternatively, facility data. The non-production data is from sources not directly related to the manufacturing process. These sources include, but are not limited to, atmospheric conditions, water conditions, gas conditions, chemical conditions, exhaust pressure, and electrical conditions. In an embodiment, a particular sample is gathered from one location by one sensor. In an embodiment, a particular sample

20 is gathered from multiple locations by multiple sensors. Alternatively, these measurements may be called facility data as they generally, but without limitation, relate to the facility in which the production takes place. Though this detailed description uses the term non-production data, or facility data, to refer to these data measurements, this is not to be taken in a limiting sense, as any data that does not

25 relate directly to the workpiece can be considered to be non-production data, or facility data, regardless of what it is actually called. This data is input into a data processor **140** for further analysis.

FIG. **2** is a pictorial representation of an exemplary combination of multiple chambers in a single fabrication machine **200** according to an embodiment of the

30 present invention. A workpiece for processing proceeds left to right in this example, being first processed by Process A **210**, then Process B **220**, and finally

Process C, **230**. Each of the constituent process may have multiple chambers for performing the similar process. In this example, Process A **210** is accomplished by one of three chambers, Chamber A_1 **211**, Chamber A_2 **212** or Chamber A_3 **213**. In this example, Process B **220** is accomplished by one chamber, Chamber B **221**. In

5   this example, Process C **230** is accomplished by one of two chambers, Chamber C_1 **231** or Chamber C_2 **232**. The number of possible routes, or groups, through Machine Y **200** can be given by the equation:

$$G_n = N_a * N_b * N_c$$

where, G_n is the number of possible routes, or groups, through Machine Y **200**, N_a is

10   the number of chambers performing Process A **210**, N_b is the number of chambers performing Process B **220**, and N_c is the number of chambers performing Process C **230**. In the example given by FIG. **2**, the number of possible routes, or groups, is 6. These groups are as follows:

Group Y_1: A_1-B-C_1

15   Group Y_2: A_1-B-C_2

Group Y_3: A_2-B-C_1

Group Y_4: A_2-B-C_2

Group Y_5: A_3-B-C_1

Group Y_6: A_3-B-C_2

20   In an embodiment, Process B **220** has two chambers performing the same process. The number of possible routes, or groups, through Machine Y **200** can be given by the equation:

$$G_n = N_a * N_b * N_c$$

where, G_n is the number of possible routes, or groups, through Machine Y **200**, N_a is

25   the number of chambers performing Process A **210**, N_b is the number of chambers performing Process B **220**, in this case 2, and N_c is the number of chambers performing Process C **230**. In this embodiment the number of possible routes, or groups, through Machine Y **200** is 12.

Providing for the general case, a multi-chambered machine, Machine Z, has

30   several chambers doing a specific process (process-1, process-2, ..., process-n).

Some of those chambers accomplish the same process. Consider the machine, Machine Z, that does m different processes in a lot of different possible routes:

Process-1: Machine Z has Z_1 chambers

Process-2: Machine Z has Z_2 chambers

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Process-m: Machine Z has Z_n chambers

Thus, the number of possible combinations, or groups, for the whole process pattern is $(Z_1 * Z_2 * \ldots * Z_n)$ in this machine.

FIG. 3 presents, at a high level, a flowchart of the method, according to an embodiment of the present invention for the handling of data from a machine, e.g., Machine Y **200** as depicted in FIG. **2**. Process A **210**, has three data sources, data from Chamber A_1 **311**, data from Chamber A_2 **312**, and data from Chamber A_3 **313**. Process B **220**, has one data source, data from Chamber B **321**. Process C **230**, has two data sources, data from Chamber C_1 **331**, and data from Chamber C_2 **332**. These data sources include, but are not limited to, test probe data, parametric data, film thickness data, critical dimension data, DC tester data, inline measurement tool data, surface characteristics data, etc. Moreover, data related to any chamber is measured after a chamber in the operation. In an embodiment, data is measured relative to a chamber after a workpiece leaves the chamber and prior to subsequent process. Data from Chambers A_1-A_3, Chamber B, and Chambers C_1-C_2 are grouped at **340** according to the possible routes a workpiece may take through the entire machine, Machine Y **200**. According to which one of these routes a particular lot of workpieces undertook, the proper data grouping is assigned to that lot at **350**. Based on the proper data grouping, specific measured data can be assigned to the data set corresponding to the particular lot of workpieces being examined. In an embodiment this measured data can include, but not be limited to, test probe data, parametric data, film thickness data, critical dimension data, DC tester data, inline measurement tool data, surface characteristics data, etc. Following proper grouping of the data and assigning that data grouping to the lot of workpieces at **350**, the data

is analyzed **360**. In an embodiment, the analysis **360** is a statistical analysis of the data. In an embodiment, the analysis **360** is a trend analysis. In an embodiment, this analysis **360** can be compared to expected conditions. Any current manufacturing conditions that depart from the expected conditions can trigger a

5 warning. In an embodiment, the warning can be an audible warning. In an embodiment, the warning can be a message sent to communications devices. In an embodiment, the warning can be a message sent over a Wide Area Network to a user or computer system. In an embodiment, a departure from expected conditions can trigger a non-manual shut down of all fabrication machines in the groups being

10 currently examined. It is to be recognized that only with quicker, accurate and more focused data analysis **360** can timely and appropriate reactions to current conditions be made.

FIG. **4** is a pictorial representation of a two step process according to an embodiment of the present invention. In this example, a workpiece undergoes

15 processing by Operation A **410** and then undergoes processing by Operation B **420**. Operation A **410** can be performed by three different machines, Machine A_1 **411**, Machine A_2 **412**, or Machine A_3 **413**. Operation B **420** can be performed by four different machines, Machine B_1 **421**, Machine B_2 **422**, Machine B_3 **423**, or Machine B_4 **424**. In an embodiment of the present invention a combination of these

20 operations can be treated as a single operation such that, instead of analyzing Operation A **410**, then Operation B **420**, Operation A-B **400** can be analyzed singly. In order to treat a plurality of operations as a single operation or machine, the route of the workpiece undergoing processing must be provided. Specifically, the multiple routes are each assigned a group. As described herein, the number of

25 groups in this example is 12, given by the equation:

$$G_n = N_a * N_b$$

where, G_n is the number of possible routes, or groups, through Operation A-B **400**, N_a is the number of machines performing Operation A **410**, and N_b is the number of machines performing Operation B **420**. In this embodiment the number of possible

30 routes, or groups, of Operation A-B **400** is 12. Here the possible groups are:

Group 1 : $A_1 - B_1$

Group 2 : $A_1 - B_2$

Group 3 : $A_1 - B_3$

Group 4: $A_2 - B_1$

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Group 12 : $A_3 - B_4$

Further, in the case such as provided in FIG. 4 the number of possible routes is the mathematical product of the number of possible individual machines performing an operation and the number of possible machines performing the other operation. However, in the general case with more then two operations being performed by multiple machines, a simple mathematical product is not sufficient. Given a multiple number of operations with a number of machines performing such operation, Operation 1 (O_1) with N_1 machines, Operation 2 (O_2) with N_2 machines, Operation 3 (O_3) with N_3 machines, through to Operation t (O_t) with N_t machines. The number of possible groups through O_1 and O_2, can be expressed as the product of N_1 and N_2. The number of the combinations of two random operations from all possible operations, t operations can be expressed as:

$$C = \frac{\{t*(t-1)\}}{2!}$$

where C is the number of combinations and t is the number of operations. The number of groups is given by the sum of the groups for all the combinations, as given by the equation:

$$X = (G_{1\&2} + G_{1\&3} + ... + G_{1\&t}) + (G_{2\&3} + G_{2\&4} + ... + G_{2\&t}) + ... + (G_{(t-1)\&t})$$

and

$$X = (N_1*N_2 + N_1*N_3 + ... + N_1*N_t) + (N_2*N_3 + N_2*N_4 + ... + N_2*N_t) + ... + (N_{t-1}*N_t)$$

where $G_{(t-1)\&t}$ is a representation of the number of combinations of machines between operation (t-1) and operation t, N_t is the number of machines performing a particular operation t and X is the number of groups for all combinations.

Generally, the number of combinations of random n operations is given by:

$$Y = tC_n$$

where Y is the total number of combinations, t is the number of operations and C_n is the number of individual machines performing a particular step. If the average of

5   the number of possible routes among the operations is assumed to be G, generally, the sum of the number of possible routes in all t operations is given by:

$$Y = \sum\nolimits_{n=1}^{t} tC_n * G$$

where Y is the total number of combinations, t is the number of operations, G is the number of possible routes and C_n is the number of individual machines performing a

10   particular step in the process

FIG. **5** presents, at a high level, a flowchart of the method, according to an embodiment of the present invention for the handling of data from a combined operation, Operation A-B **400** as depicted in FIG. **4**. Operation A **410**, has three data sources, data from Machine A_1 **511**, data from Machine A_2 **512**, and data from

15   Machine A_3 **513**. Operation B **420** has four data sources, data from Machine B_1 **521**, data from Machine B_2 **522**, data from Machine B_3 **523**, and data from Machine B_4 **524**. These data sources include, but are not limited to, test probe data, parametric data, film thickness data, critical dimension data, DC tester data, inline measurement tool data, surface characteristics data, etc. This data is grouped at **540**

20   according to the possible routes a workpiece may take through the combined operation. According to which one of these routes, or groups, a particular lot of workpieces undertook, a proper data grouping is assigned to that lot at **550**. Based on the proper data grouping, specific measured data can be assigned to the data set corresponding to the particular lot of workpieces being examined. In an

25   embodiment this measured data can include, but not be limited to, test probe data, parametric data, film thickness data, critical dimension data, DC tester data, inline measurement tool data, surface characteristics data, etc. Following proper grouping of the data and assigning that data grouping to the lot of workpieces at **550**, the data is analyzed **560**. In an embodiment, the analysis is a statistical analysis of the data.

30   In an embodiment, the analysis **560** is a trend analysis. In an embodiment, this analysis **560** can be compared to expected conditions. Any current manufacturing

conditions that depart from the expected conditions can trigger a warning. In an embodiment, the warning can be an audible warning. In an embodiment, the warning can be a message sent to communications devices. In an embodiment, the warning can be a message sent over a Wide Area Network to a user or computer

5   system. In an embodiment, a departure from expected conditions can trigger a non-manual shut down of all fabrication machines in the groups being currently examined. It is to be recognized that only with quicker, accurate and more focused data analysis 560 can timely and appropriate reactions to current conditions be made.

10   In an embodiment of the present invention, the data from each sorted group can be graphed and reported automatically. In an embodiment of the present invention, specific specifications can be established for each report, including without limitation, graphs, charts, data. Further, the results and graphs can be automatically provided to the engineers responsible for the production of the

15   workpieces being processed. With quicker data analysis by grouping or combining processes, engineers can quickly respond to conditions affecting the performance of the manufacturing process and reduce the amount of wasted material.

FIG. 6 presents, at a high level, a flowchart of the method, according to an embodiment of the present invention for the collection and analysis of data on a

20   particular lot of workpieces from production sources and non-production sources. The data sources 300, 500, 605, represent an exemplary set of data sources to be analyzed. It is recognized that though three data sources are represented, any number of data sources may be present. These data sources may be from production sources and from non-production sources. Data source 300 represents data from a

25   group assigned to a particular lot of workpieces as contemplated by FIG. 2, and processed according to the method embodied in FIG. 3. Data source 500 represents data from a group assigned to a particular lot of workpieces as contemplated by FIG. 4, and processed according to the method embodied in FIG. 5. Data source 605 represents any of the other variety of data sources available in a manufacturing

30   facility. In an embodiment of the present invention, data source 605 represents a non-production data source. These sources include, but are not limited to,

atmospheric conditions, water conditions, gas conditions, chemical conditions, exhaust pressure, and electrical conditions. In an embodiment, a particular sample is gathered from one location by one sensor. In an embodiment, a particular sample is gathered from multiple locations by multiple sensors. Alternatively, these

5   measurements may be called facility data as they generally, but without limitation, relate to the facility in which the production takes place. Though this detailed description uses the term non-production data, or facility data, to refer to these data measurements, this is not to be taken in a limiting sense, as any data that does not relate directly to the manufacturing process can be considered to be non-production

10   data, or facility data, regardless of what it is actually called. In the case that multiple data points are collected and assigned to a particular lot of workpieces, a calculation **610** may be performed to further combine those data points into a single data point. In an embodiment, this calculation **610** may be a weighted mean calculation, weighting the data for time, location, etc. The data can then be keyed

15   **611** to some unique value allowing for non-manual relation of the three data sources **650**. Following the relation of the data at **650**, the data can be quickly analyzed at **660**. In an embodiment, this analysis **660** is a statistical analysis. In an embodiment, this analysis **660** is a trend analysis. In an embodiment of the present invention, this analysis **660** is very focused on the particular lot of workpieces being

20   considered. By not including data from operations, machines, processes, chambers and the like that did not affect the lot of workpieces being considered, the data set associated with that lot of workpieces being considered can be smaller, representing a computational cost saving, and allowing for quicker data analysis **660**. A quicker data analysis **660** further provides for quicker reaction to current manufacturing

25   conditions.

FIG. **7** depicts a block diagram of a system for implementing an embodiment of the invention analogous to the data processor **140** shown in FIG. **1**. Illustrated are a server **701** connected to a computer **702** via a network **710**. Although one server **701**, one computer **702**, and one network **710** are shown, in other

30   embodiments any number or combination of them may be present. Although the

server **701** and the network **710** are shown, in another embodiment they may not be present.

The computer **702** may include a processor **730**, a storage device **740**, an input device **760**, and an output device **750**, all connected via a bus **770**.

5   The processor **730** may represent a central processing unit of any type of architecture, such as a CISC (Complex Instruction Set Computing), RISC (Reduced Instruction Set Computing), VLIW (Very Long Instruction Word), or a hybrid architecture, although any appropriate processor may be used. The processor **730** may execute instructions and may include that portion of the computer **702** that

10   controls the operation of the entire computer. Although not depicted in FIG. 7, the processor **730** typically includes a control unit that organizes data and program storage in memory and transfers data and other information between the various parts of the computer **702**. The processor **730** may receive data from the input device **760**, may read and store code and data in the storage device **740**, may send

15   data to the output device **750**, and may send and receive code and/or data to/from the network **710**.

Although the computer **702** is shown to contain only a single processor **730** and a single bus **770**, the present invention applies equally to computers that may have multiple processors and to computers that may have multiple buses with some

20   or all performing different functions in different ways.

The storage device **740** represents one or more mechanisms for storing data. For example, the storage device **740** may include read only memory (ROM), random access memory (RAM), magnetic disk storage media, optical storage media, flash memory devices, and/or other machine-readable media. In other

25   embodiments, any appropriate type of storage device may be used. Although only one storage device **740** is shown, multiple storage devices and multiple types of storage devices may be present. Further, although the computer **702** is drawn to contain the storage device **740**, it may be distributed across other computers, for example on server **701**.

30   The storage device **740** includes a controller **745**, which in an embodiment may include instructions capable of being executed on the processor **730** to carry

out the functions of the present invention. In another embodiment, some or all of the functions of the present invention may be carried out via hardware in lieu of a processor-based system. Although the controller **745** is shown to be contained within the storage device **740** in the computer **702**, some or all of the controller **745**

5   may be distributed across other systems, for example on the server **701** and accessed via the network **710**.

The input device **750** may be a keyboard, pointing device, mouse, trackball, touchpad, touchscreen, keypad, microphone, voice recognition device, or any other appropriate mechanism for the user to input data to the computer **702**. Although

10   only one input device **760** is shown, in another embodiment any number and type of input devices may be present.

The output device **750** is that part of the computer **702** that communicates output to the user. The output device **750** may be a cathode-ray tube (CRT) based video display well known in the art of computer hardware. But, in other

15   embodiments the output device **750** may be replaced with a liquid crystal display (LCD) based or gas, plasma-based, flat-panel display. In another embodiment, the output device **750** may be a speaker. In still other embodiments, any appropriate output device suitable for presenting data may be used. Although only one output device **750** is shown, in other embodiments, any number of output devices of

20   different types or of the same type may be present.

The bus **770** may represent one or more busses, e.g., PCI, ISA (Industry Standard Architecture), X-Bus, EISA (Extended Industry Standard Architecture), or any other appropriate bus and/or bridge (also called a bus controller).

The computer **702** may be implemented using any suitable hardware and/or

25   software, such as a personal computer or other electronic computing device. Portable computers, laptop or notebook computers, PDAs (Personal Digital Assistants), two-way alphanumeric pagers, keypads, portable telephones, appliances with a computing unit, pocket computers, and mainframe computers are examples of other possible configurations of the computer **702**. The hardware and software

30   depicted in FIG. **7** may vary for specific applications and may include more or fewer elements than those depicted. For example, other peripheral devices such as

audio adapters, or chip programming devices, such as EPROM (Erasable Programmable Read-Only Memory) programming devices may be used in addition to or in place of the hardware already depicted.

The network **710** may be any suitable network and may support any
5   appropriate protocol suitable for communication between the server **701** and the computer **702**. In an embodiment, the network **710** may support wireless communications. In another embodiment, the network **710** may support hard-wired communications, such as a telephone line or cable. In another embodiment, the network **710** may support the Ethernet IEEE (Institute of Electrical and Electronics
10   Engineers) 802.3x specification. In another embodiment, the network **710** may be the Internet and may support IP (Internet Protocol). In another embodiment, the network **710** may be a local area network (LAN) or a wide area network (WAN). In another embodiment, the network **710** may be a hotspot service provider network. In another embodiment, the network **710** may be an intranet. In another
15   embodiment, the network **710** may be a GPRS (General Packet Radio Service) network. In another embodiment, the network **710** may be any appropriate cellular data network or cell-based radio network technology. In another embodiment, the network **710** may be an IEEE 802.11x wireless network. In still another embodiment, the network **710** may be any suitable network or combination of
20   networks. Although one network **710** is shown, in other embodiments any number of networks (of the same or different types) may be present.

As was described in detail above, aspects of an embodiment pertain to specific apparatus and method elements implementable on a computer or other electronic device. In another embodiment, the invention may be implemented as a
25   program product for use with an electronic device. The programs defining the functions of this embodiment may be delivered to an electronic device via a variety of signal-bearing media, which include, but are not limited to:

(1) information permanently stored on a non-rewriteable storage medium, e.g., a read-only memory device attached to or within an electronic device, such as a
30   CD-ROM readable by a CD-ROM drive;

(2) alterable information stored on a rewriteable storage medium, e.g., a hard disk drive or diskette; or

(3) information conveyed to an electronic device by a communications medium, such as through a computer or a telephone network, including wireless

5   communications. Such as the information from the operations **110, 120, 130** of FIG. **1** to the data processor **140** of FIG. **1** via the network **710** of FIG. **1**, further depicted and described above and in FIG. **7**.

Such signal-bearing media, when carrying machine-readable instructions that direct the functions of the present invention, represent embodiments of the

10   present invention.

FIG. **8** depicts a pictorial representation of a simplified manufacturing process for workpieces, according to an embodiment of the present invention. A workpiece for processing **105** is processed by the operation **710** and a resulting end product **106** is produced. Data is measured on the operation **710** that is applicable to

15   the workpiece being processed **107**. This data is transmitted over a network to a data processor for storage, analysis and examination. According to an embodiment of the present invention, the operation **710** can be the specific route that the workpiece **107** took through the entire manufacturing facility **100**. This has the benefit of only storing measured data that is applicable to the route that a workpiece

20   took in a data set for that workpiece. It is to be recognized that a manufacturing facility represents hundreds of processes, fabrication machines, operations, manufacturing chambers and the like. Storing data from these various data sources and performing non-specific and non-focused data analysis meant to yield some information in regards to a particular lot of workpieces is an extremely large

25   computational cost. This cost is manifested in large delays of time between measurement of the data and response to the conditions that are being measured. In extreme conditions this may result in substandard product **106** leaving the manufacturing facility **100**. In an embodiment, it could also result in workpieces proceeding too far along the manufacturing line from where the workpieces

30   encountered out of specification conditions. This could mean that the workpieces have proceeded past a point that can not be recovered from, resulting in wholesale

scrapping of workpieces. An analysis on a focused, specific data set corresponding to a particular lot of workpieces can reduce the likelihood of such a result, as operators can react quickly to out of specification conditions. In an embodiment, a system non-manually reacts to out of specification conditions.

5   There are distinct advantages for this combination and aggregation as described herein. It allows for quicker more focused data analysis of conditions that directly affect the quality of the produced workpieces. It reduces the amount of extraneous data in a data set that do not directly relate to a particular production lot of workpieces or group. Quicker analysis also provides for quicker reaction,

10   allowing operators and engineers to quickly respond to conditions, address the problems, and reduce the amount of product being affected by those conditions.